CIRRELT

CIRRELT-2025-26

Measuring and Modeling Sustainability in Food Bank Operations

Asena Kaplan
Julie Paquette
Burcu Balçik

Août 2025

Bureau de Montréal
Université de Montréal
C.P. 6128, succ. Centre-Ville
Montréal (Québec) H3C 3J7
Tél : 1-514-343-7575
Télécopie : 1-514-343-7121

Bureau de Québec
Université Laval,
2325, rue de la Terrasse
Pavillon Palasis-Prince, local 2415
Québec (Québec) G1V 0A6
Tél : 1-418-656-2073
Télécopie : 1-418-656-2624

Measuring and Modeling Sustainability in Food Bank Operations

Asena Kaplan[1], Julie Paquette[2*], Burcu Balçik[1]

1. Industrial Engineering, Ozyegin University, Istanbul, Turkey
2. Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT) and Department of Logistics and Operations Management, HEC Montréal

Abstract. Food banks play a critical role in enhancing food security and reducing food waste by partnering with various stakeholders, including governments, non-profit organizations, local donors (e.g. supermarkets, hotels), and charitable agencies to collect surplus food and distribute it to those in need. The sustainability of food bank operations hinges on efficient resource (funds, human resources, etc.) utilization, equitable food distribution, and addressing food insecurity effectively. It is also important for food banks to align their operations with economic, environmental, and social sustainability dimensions. Addressing conflicting objectives and understanding the trade-offs between them is crucial to support data-driven decision-making for food allocation and distribution. To understand how sustainability is incorporated into food bank operations, we conduct a case study with a provincial Canadian food bank and a literature review on food bank operations to understand the sustainability goals of food banks and identify how these goals are incorporated as sustainability metrics in decision-making models.

Keywords: Food bank operations, sustainability metrics, sustainable development goals

---

* Corresponding author: julie.paquette@hec.ca

Dépôt légal – Bibliothèque et Archives nationales du Québec

Bibliothèque et Archives Canada, 2025

1 Introduction

Food security is the state in which all people have steady access to sufficient, nutritious, and safe food that meets their dietary needs for an active and healthy life (Radimer and Radimer, 2002). Despite the efforts to define and enhance food security, one in ten people in the world suffered from food insecurity in 2020; while 13.3% of the harvested food never reached consumers, and 17% of consumer-reached food was wasted in households, food services, or the retail sector (United Nations, 2022a). Food insecurity is driven by numerous factors such as climate change (Chavez et al., 2015; United Nations, 2022a), armed conflicts (Blake and Voegele, 2022; National Geographic Society, 2022; United Nations, 2022a), and economic recession leading to unemployment and poverty (FAO and WHO, 2022; United Nations, 2022a). The COVID-19 pandemic has further exacerbated the global hunger crisis. In addition, food waste at different levels (harvesting, retail, home) substantially deters efforts to achieve global food security (United Nations, 2025). Therefore, the urgency for global and local organizations to combat food insecurity and food loss increases since the mentioned factors continue to intensify (Bruce-Lockhart and Terazono, 2022).

The food insecurity problem is also emphasized in many of the United Nations Sustainable Development Goals (UNSDGs) (United Nations, 2022b). UNSDGs aim to eradicate inequalities, poverty, and hunger; they advocate for global health and well-being while promoting economic growth and advancements across all sustainability dimensions (economic, social, and environmental) (United Nations, 2015). Each UNSDG aligns with one or more sustainability dimensions and proposes comprehensive solutions to emerging problems. While some UNSDGs directly focus on reducing food insecurity and decreasing food waste, others implicitly mention or benefit from improved food security and reduced food waste. Specifically, UNSDG #2, "Zero Hunger", aims to achieve global food security, and the third target of UNSDG #13: "Ensuring Sustainable Consumption and Production Patterns" is about reducing food loss at all levels and developing sustainable practices.

Food banks (FBs) are humanitarian organizations that operate as an intermediary between the donors (e.g. supermarkets, restaurants, food processors, or producers) and partner agencies that provide food to beneficiaries (people facing food insecurity). In an effort to decrease food waste and tackle food insecurity, FBs collect the surplus and/or expired but safe-to-consume food as donations, transport and store them in their warehouses, and redistribute them to their partner agencies (food pantries) or directly to beneficiaries (Feeding America, 2022). Due to their mission, FB operations are directly related to UNSDG #2 "Zero Hunger", specifically advocating for social and environmental sustainability. As sustainability has become a critical consideration for organizations from different sectors, FBs must also address sustainability concerns in their operations. Therefore, FBs must align their operations with three sustainability dimensions (economic, social, and environmental) to ensure effective and long-lasting solutions (Zarei et al., 2019) to achieve UNSDGs.

To put sustainability into action, FBs must define their sustainability goals. A goal is a broad, overarching aim or desired outcome that an organization strives to achieve. In the context of FBs, a sustainability goal could be, for example, to reduce food waste or to maintain equity while redistributing food. These goals should then be operationalized through metrics. A metric is a specific, quantifiable measure used to track progress toward achieving a goal. Metrics provide concrete data that can be analyzed to assess performance. For example, a metric for the goal of reducing food waste could be the percentage of food diverted from landfills. These metrics can then be integrated into decision-making tools to ensure operational, tactical, and

strategic decisions are aligned with sustainability goals.

Operations Research (OR) techniques are widely used to support designing and managing FB operations, provide evidence-based decision-making, and enable evaluating major operational performance in terms of efficiency, effectiveness, and equity. The literature is rich in models and methods that analyze the trade-off between efficiency, effectiveness, and equity (see Bonku et al. (2024); Hasnain et al. (2021); Mahmoudi et al. (2022)). However, an explicit discussion on sustainability goals and metrics does not exist to the best of our knowledge.

Although there exists a rich literature employing operations research methods to support decision-making for improving FB operations across various goals and contexts and detailed review studies (see review papers Mahmoudi et al. (2022); Rivera et al. (2023)), sustainability goals and metrics in FB supply chain (FBSC) decision-making models are yet to be analyzed. Indeed, recent review papers on FB operations (Mahmoudi et al., 2022; Rivera et al., 2023) primarily focus on model formulation, solution methods, objective function structures, and validations of these approaches. Moreover, Kafa and Jaegler (2021) focus on only one sustainability metric, food waste, and waste quantification in the FB supply chain by reviewing 117 articles. While other studies are incorporating sustainability concerns into decision-making models in different types of supply chains, Nawazish et al. (2023) point out a gap and a future research direction for defining sustainability metrics in humanitarian supply chains. Therefore, to reduce this gap, this study aims to identify and present such sustainability goals and metrics, and examine how they are addressed by OR methodologies. Even though existing research has covered the trade-offs between efficiency, effectiveness, and equity objectives, this is the first study that explores how to measure and model sustainability in FB operations.

Our main research question is composed of three parts: (1) What are the main goals of FB practitioners regarding sustainability? (2) What are the sustainability metrics in the existing OR models that focus on FB operations? (3) Which sustainability metrics can be adapted or developed to be included in OR models for the FB-specific context?

To achieve this, we first present an overview of FBSC and sustainability concerns in supply chains in Section 2. In Section 3, we explain our research methodology based on a case study and a literature review. Section 4 presents our case study that identifies the sustainability goals pursued by FB managers from a partner organization in Canada. A literature review of FB operations regarding the inclusion of different sustainability metrics is provided in Section 5. Section 6 concludes our paper.

2 Background: FBSC and Sustainability

FBSC, while categorized within the humanitarian supply chain (HSC), also exhibits some properties of the commercial supply chain (CSC), necessitating a positioning of the unique FBSC context. In this section, we first position FBSC compared to HSC and CSC. Then, since some sustainability goals and metrics for the FBSC could be adapted or borrowed from the HSC and CSC literatures, we explain commonly used sustainability metrics in these literatures.

2.1 Definition and Positioning of FBSC

All supply chains aim to maximize their generated value. The definition of ”value” distinguishes different supply chain types. Specifically, in CSC, the main objective is maximizing the profit of the organization, whereas in HSC, the value is created by helping communities in need (Chopra and Meindl, 2007), (Van Wassenhove, 2006). Moreover, humanitarian organizations have different specific missions and therefore tailored SC designs. Van Wassenhove (2006) and Beamon and Balcik (2008) explain that there are two main categories of operations in the humanitarian space: *(1): disaster relief activities* which focus on the post-disaster relief and require high responsiveness and agility, and *(2): development activities* which aim to minimize human suffering through long-term infrastructure aid programs that ensure communities can eventually function independently, emphasizing efficiency. Narayanan and Altay (2021) extend this classification by adding a new type of activity under HSC: “sustenance aid”. In sustenance aid, as Narayanan and Altay (2021) explain, the organization’s aim is not to target the root causes of an ongoing problem but to help vulnerable people manage and overcome a challenging situation, i.e. sustenance of the populations. FBSC thus falls into this last category, therefore FBs can be called ambidextrous organizations. Specifically, FBs focus on providing food to people in need rather than studying and targeting deeper problems in a society that causes food insecurity in the first place.

2.2 Sustainability in Supply Chains

Since the main goals and the conditions under which the SC activities are performed vary, the sustainability goals pursued in different SCs also differ. Specifically, economic sustainability is the major driver of a CSC, since ensuring economic growth and continuity of the organization is the primary responsibility of a for-profit business. Social sustainability (such as equitable aid distribution) is a major concern in HSC for preventing human suffering and improving the living conditions of communities. Moreover, Narayanan and Altay (2021) highlights that the primary sustainability goals in HSC can differ from each other due to factors such as planning time available, uncertainty in demand and supply, reliability, and information-sharing opportunities. Specifically, in disaster aid, quick response to recover pre-disaster conditions is the main goal (social sustainability), while development activities usually focus on the reconstruction of communities (economic sustainability) (Narayanan and Altay, 2021). Ambidextrous organizations such as FBs mainly work to reduce waste generated, therefore by nature, their primary goal would be environmental sustainability (Narayanan and Altay, 2021). However, while targeting one sustainability dimension, other dimensions should not be ignored.

Identifying sustainability metrics is crucial to quantifying and measuring the economic, environmental, and social effects of operations and systems and is gaining increasing interest (Ahi and Searcy, 2015). McElroy and Van Engelen (2012) emphasize the importance of developing sustainability metrics for specific contexts. Different supply chains have been reviewed to understand which sustainability metrics were specifically applicable to their context. We examined eight literature reviews about sustainability metrics in different CSCs to identify commonly used metrics. Specifically, Calzolari et al. (2022) focus on circular supply chain performance and review 203 articles to identify the mentioned sustainability metrics. Eskandarpour et al. (2015) review 87 articles on general supply chain network design. Then, 115 articles on the sustainability of manufacturing supply chains were examined by Eslami et al. (2019). Supply chain design

on real cases with 113 articles was inspected by Moreno-Camacho et al. (2019). Qorri et al. (2018) review 104 papers on sustainable and green supply chain management, whereas decision support tools for green and sustainable supply chains were examined by Taticchi et al. (2015) using 384 articles. Performance measurement in green supply chains was covered by Tuni et al. (2018), who reviewed 78 articles on the topic. Finally, Zimmer et al. (2016) focus on sustainable supplier selection and management through 143 articles. We could find only one literature review paper, the one by Nawazish et al. (2023), which focused on sustainability concerns in HSC. The scopes and number of articles considered in each of these review papers are presented in Table 4 in Appendix D.

We now provide an overview of the most common sustainability metrics that were included in the CSC and HSC literature, based on these review papers.

The economic sustainability dimension is linked to the economic performance of an organization. Cost (e.g. logistic cost, storage costs, etc.), revenue and profit metrics are easily and vastly addressed in decision-making models both in CSCs to increase the profits, and in HSCs to minimize the costs or stay within a limited budget.

The environmental sustainability dimension considers the effect of SC on the environment, including but not limited to greenhouse gas (GHG) emissions, air/water pollution, use of resources, waste on land, etc. This dimension, similar to the economic dimension, is widely considered in the CSC literature. It can be addressed by incorporating emission equivalent metrics to the objective function to minimize, or as a constraint to limit. Other metrics are the amount of waste that is prevented, therefore not sent to the landfill, or cumulative energy use. Most studies model environmental impacts by measuring the CO_2 emissions, the amount of waste generated/prevented, or the amount of resources used.

The social sustainability dimension is about the effect of operations on communities and society. Concerns such as creating safe, inclusive, and equal job opportunities and workplaces, promoting equality among people, or helping people out of poverty fall under social sustainability. Social sustainability is addressed less than the economic and environmental dimensions in decision-making models due to the difficulty in quantifying it. In CSCs, two of the most popular ways to incorporate social sustainability are to consider the number of jobs created or consider the working environment and conditions (exposure to chemicals, or employee benefits such as education or time-off opportunities). In HSCs, the most prevalent social sustainability metric is equity, since it is crucial to ensure a fair distribution of donations so that no individual is at a disadvantage compared to others.

3 Research Methodology

We address our three research questions (see Section 1) using a multi-method approach. First, to gain deeper insights into the sustainability goals of FBs (RQ1), a case study was undertaken with a FB network in Quebec, Canada. Second, we perform a literature review to identify the sustainability metrics used in operations research models focusing on FB donation collection and distribution networks (RQ2). Lastly, we synthesize our findings and draw conclusions about the sustainability metrics that can be adapted or developed to be included in OR models in the FB-specific context (RQ3). This section explains the research methodology followed for the case study and literature review.

3.1 Case study methodology

The case study is based on a convenience sample of 18 FBs part of the Food Bank Quebec (FBQ) network. This organization was selected due to one researcher's eight years of collaboration with them and their extensive network of FBs (see Figure 1). FBQ helps 870,000 people monthly and works with 19 regional FBs and more than 1,300 local community organizations (Food Banks Quebec, 2024). In 2022-2023, FBQ redistributed 19.2 million kilos of food donations, while combined efforts of FBQ and its local food agencies networks resulted in the redistribution of 43.8 million kilos (Food Banks of Quebec, 2023). The flow of these donations is pictured in Figure 2. The unit of analysis is at the FB level. Each FB is in a different region (urban or rural) and manages varying volumes of food donations, providing a diverse range of cases (Eisenhardt, 1989; Yin, 2009). This diversity suggests that the FBs may have different sustainability goals or concerns.

For each case, various sources of data were used: semi-structured interviews with FB operations managers or director about their operations and goals (see the questions asked in Appendix B), reviews of FB websites, a questionnaire about sustainability goals for the managers and visits to two FBs. The operations managers or directors were selected as the unique respondents since they have extensive knowledge of the operations and strategic objectives of the FB. We also performed an interview with the operations managers of the FB network.

Each interview lasted between one and two hours and aimed to gain a better understanding of the operations performed by FBs such as transportation, warehousing, distribution, etc. Through these interviews, we were able to identify sustainability goals pursued by the managers. By employing a combination of sources, i.e. triangulation, the results have enhanced validity (McCutcheon and Meredith, 1993; Yin, 2009).
Once the data was collected, the interviews were transcribed and analyzed. Coding of those transcripts was done using thematic analysis (Boyatzis, 1998). Each theme identified a specific sustainability goal. Once all the transcripts were analyzed, the coder regrouped similar themes together.

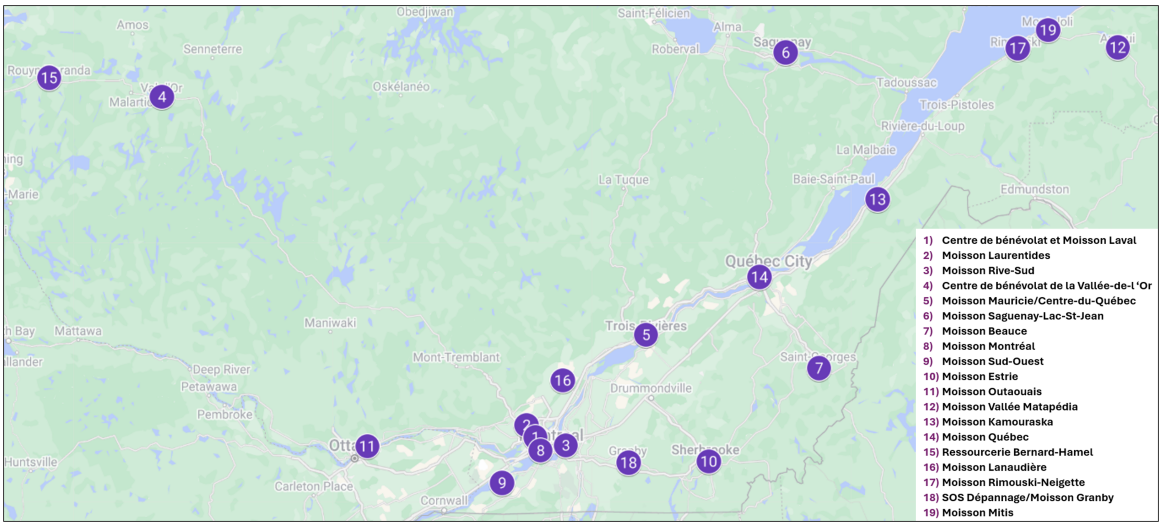

Figure 1: Food Bank Québec's network

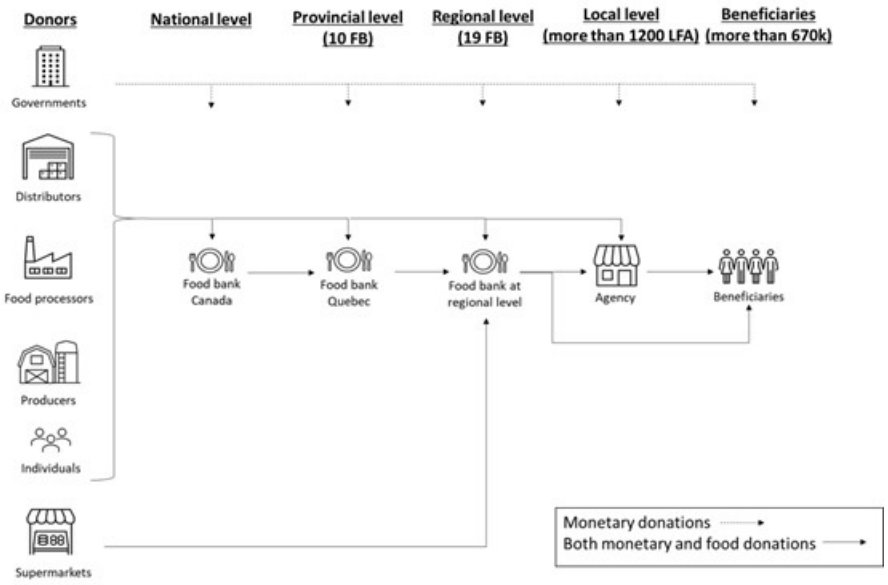

Figure 2: Flow of food donations in the network of Food Bank Québec

3.2 Literature review methodology

To identify the sustainability metrics included in OR models for the FB context, we have performed a literature review (RQ2). For this purpose, we searched Scopus and Web of Science (WoS) databases with the keywords "food bank", "food rescue", and "hunger relief" and extracted outputs on December 10, 2024. We limited our research to subject areas "business, management and accounting" in Scopus, and "operations research management science", "management" and "industrial engineering" in WoS.

Various types of problems can be considered in the FBSC context. In their review, Rivera et al. (2023) propose a framework to group and evaluate contributions to the FBSC literature based on three categories: *supply* (forecasting and managing donations), *food banks* (anything related to FB operations such as network design, resource allocation, inventory management, etc.- i.e. "FB logistics), and *demand* (forecasting and characterization of demand). In this study, we specifically focus on FB logistics, which fits under the "food banks" category. We do not consider studies about estimating the demand and/or the supply, or conceptual works that develop a framework for FB operations. We focus on peer-reviewed articles written between the years 2013-2024 that were published in English. A total of 126 and 57 abstracts from Scopus and WoS, respectively, were inspected. According to their relevance to our context, based on the information in their abstracts, a total of 39 articles were selected to read and review in detail. The others were discarded because they did not meet the previously mentioned criteria. Upon reading the articles, we concluded that 32 of them were relevant to our research questions.

To make sure we did not overlook important papers, we also examined the latest literature review studies about FB operations (Mahmoudi et al., 2022; Rivera et al., 2023) and compared the list of articles reviewed with ours. We had 9 new articles, where 7 of them were published after their reviews, and they had one additional article that matched our subject but not our selected keywords. So, we added that one article that was not in our list of selected articles to review. Therefore, we reviewed 33 articles (24 of them are the same as Mahmoudi et al. (2022); Rivera et al. (2023), with additional papers that were published recently) on FB

operations to understand which sustainability goals were addressed. Our literature review methodology is summarized in Figure 3. Even though we did the research at different times, we almost arrived at the same set of articles with Mahmoudi et al. (2022); Rivera et al. (2023).

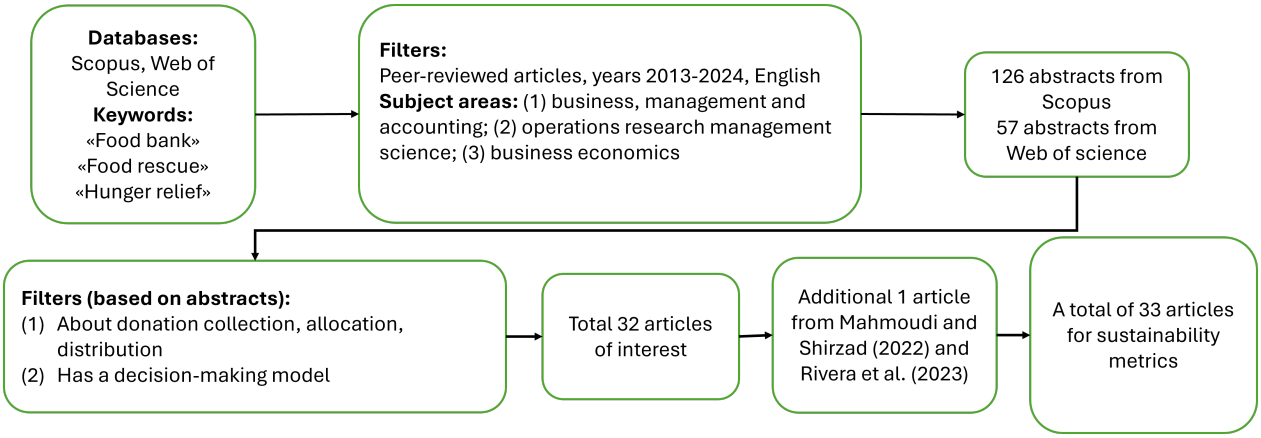

Figure 3: Research methodology flowchart

To answer our last research question, we synthesize our findings about FB sustainability goals and metrics addressed in the FBSC context. Specifically, we present a discussion on the sustainability goals of FBs from the case study, explore existing sustainability metrics with the literature review, link the findings from both, and point out future discussions.

4 Case Study Results: Sustainability Goals Identified

Based on the interviews with the regional FB managers, the provincial FB manager, and the information available on their websites, it was possible to identify ten sustainability goals that were of concern to FB managers. These are divided under each sustainability dimension and described in the FB-specific context.

4.1 Economic Sustainability

In terms of economic sustainability, minimizing various operational costs (transportation, warehousing, working hours, etc.) was often mentioned by FB operations managers or directors during the interviews. Indeed, this quote from a respondent shows the importance of minimizing costs: “in a food bank, all the services we offer incur costs and do not generate revenue, unlike a thrift store, for example” (respondent 18, freely translated from French). Therefore, the economic objective is crucial to ensure the efficient use of resources (financial, human, or material) as these resources are limited. However, since FBs are not-for-profit organizations, efficiency cannot be the only objective, and it must be balanced with equity and effectiveness (Sengul Orgut et al., 2016).

4.2 Environmental Sustainability

In terms of environmental sustainability, three different goals were identified. First, minimizing the waste of food is a major concern for FBs as it is part of their mission. By receiving donations of food

that would be discarded and sent to landfill otherwise, FBs reduce the quantity of food waste in general. Specifically, FBs in Quebec have a program through which they have agreements with supermarkets to obtain end-of-life products. These products are redistributed or transformed by FBs and complement the in-kind food donations received from other donors and the food bought by FBs. One FB even explained that they quantify their impact by estimating the GHG emission saved by these products to landfills instead. Moreover, in their own operations, FBs will very rarely send to landfill donations they have received unless the products are already not good for consumption. Many initiatives are taken by FBs to offer products with a very short life duration to beneficiaries, such as making them available through accessible pantries or refrigerators, transforming the products, or freezing the products. Another initiative that was also discussed by a few FBs was that they sometimes share a donation received by local donors to other FBs in the network when they reach their maximum capacity.

Secondly, a manager mentioned their efforts to minimize GHG emissions by optimizing transportation activities. However, despite this concern, they do not currently track their emissions or have specific reduction goals. Two managers considered purchasing an electric vehicle for distribution, but the acquisition cost was prohibitive for a not-for-profit organization.

Thirdly, several managers have highlighted their efforts to maximize the recycling of the packaging material. For instance, they often reuse the boxes in which products are delivered to repack items for redistribution to agencies, thereby streamlining handling and transportation operations. As one respondent humorously noted: “food banks, we’re great at using banana boxes!” (respondent 15, freely translated from French).

4.3 Social Sustainability

Social sustainability is related to the rationale for the existence of FBs as frequently stressed in their mission statements. For example, one FB highlights their mission as ensuring fair redistribution of food to organizations and individuals, as well as to develop, support, and promote volunteerism and social assistance. Specifically, in terms of social sustainability, six goals were identified. The primary goal, emphasized by several FB managers, is ensuring equity in food redistribution to agencies. Respondent 9 explained that they use the number of beneficiaries served by each agency and the type of households (e.g., single, adults, family with children, etc.) to allocate food quantities. Each FB has a method to calculate the weekly amount of each food category that an agency can receive, ensuring they can adequately serve their beneficiaries. This goal and the concept of equity are central to the mission of a FB.

Secondly, maximizing the variety of food obtained and distributed is crucial, not just the quantity. For instance, providing only potatoes for a week would not allow agencies to prepare nutritious meals or food baskets. Therefore, ensuring a diverse range of food items is essential for agencies to effectively offer their services. According to several managers, the importance of this consideration has grown in recent years.

Thirdly, another goal mentioned by FB managers is maximizing the nutritional quality of the food distributed, in addition to variety. Sometimes, FB managers receive donation offers that lack nutritional value, such as chips, soft drinks, or candies. Accepting these donations consumes resources for transportation and warehousing that could have been more useful for more nutritious products. However, to maintain good relationships with donors, FBs often accept these donations. As one respondent noted: “It’s difficult in FBs to make decisions based solely on, “Do I have space? Do I have a need?”, it will also be based on the

relationship with the donor" (respondent 3, freely translated from French). Maintaining these relationships is crucial, as donors may provide more nutritious food in the future.

The fourth goal in the social dimension mentioned by respondents is the reliance on both employees and volunteers to perform FB operations. Volunteers are invaluable human resources, as FBs typically lack sufficient staff to perform all their activities. Volunteers are often assigned to simpler tasks that require minimal training. However, employees still need to explain these tasks to volunteers. Recurrent volunteers are particularly important because they require less training time. To maintain a stable volunteer base and fulfill their mission, many FBs participate in social reintegration and employability programs. These programs not only help achieve social integration but also enhance community outreach. This is supported by one FB's mission statement: "Our mission is to ensure food security for vulnerable individuals while promoting social and employment integration" (Moisson Mauricie Centre-du-Québec (2025), freely translated from French). This FB also quantifies this by the number of people who develop their skills, interpersonal abilities, and expertise.

The fifth goal mentioned by a few managers is ensuring a secure work environment, mostly for volunteers who may not have adequate training to operate the handling equipment. As one respondent noted: "The volunteers, I want them to stay in the sorting area, and they won't go beyond that because, from a health and safety perspective, I don't want them moving around where the pallet jack is operating" (respondent 10, freely translated from French). Additionally, food boxes can be heavy and it is important for volunteers to respect their own physical capacity. Creating a safe, open, and caring environment encourages volunteers to return. This social goal can also help FBs reduce costs by utilizing volunteers instead of employees.

Finally, the last goal mentioned by some respondents is to reduce delays and increase direct redistribution to ensure food freshness. Most regional FBs usually do not serve beneficiaries directly; instead, they send food to agencies that serve the beneficiaries. However, as mentioned previously, some FBs have accessible refrigerators or pantries to distribute highly perishable food that would not last through the regular distribution network. By achieving this social goal, they simultaneously achieve an environmental goal.

5 Review of Sustainability Metrics and Models in Food Bank Operations

We reviewed 33 articles on FB logistics under the framework of (Rivera et al., 2023), excluding problems focusing on forecasting or managing supply and/or demand. Among the reviewed papers, some focus on different variants of resource allocation from donors to beneficiaries (or directly to families in need), some address both the allocation and distribution (routing) of the donations, and others concentrate on the routing of donation pickups and deliveries, considering different variants.

5.1 Analysis of Sustainability Metrics and Models from FBSC Literature

In the 33 articles reviewed, a combination of social and environmental metrics and a combination of all three metrics were widely studied. Also, the number of studies that consider economic sustainability is unexpectedly fewer than those that consider either environmental and/or social sustainability, likely because FBs are not-for-profit organizations. The Venn chart given in Figure 4 presents the number of articles that explicitly mention each pillar (or a combination of several pillars) of sustainability.

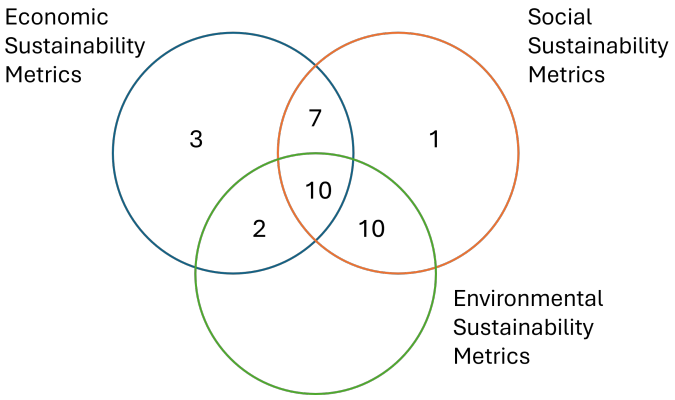

Figure 4: Sustainability Dimensions in FBSC Literature

When there are multiple conflicting objectives or metrics, decision-makers often have to choose a solution among multiple solutions that perform better for different objectives (Zajac and Huber, 2021). Therefore, trade-offs among these solutions should be evaluated, and then the decision-maker can select a solution according to their priorities. This also requires an in-depth analysis of how different metrics were integrated to balance potential trade-offs using different multi-criteria decision-making (MCDM) approaches. Moreover, out of 33 articles reviewed for our study, 26 of them have used MCDM approaches, which made reviewing MCDM models addressing sustainability necessary. Therefore, in our study, in addition to the sustainability metric definitions, we cover different MCDM approaches utilized to balance them. We borrow the notation of Gutjahr and Nolz (2016) to refer to different MCDM approaches in this paper. A brief explanation of each concept from Gutjahr and Nolz (2016) along with comments from the literature is provided in Section 5.1.2.

Table 1 presents for each paper a brief problem definition, followed by the used MCDM solution approach and the addressed sustainability metrics for all dimensions. Specifically, the "Prob. Def." columns classify the FB operation considered in each article under allocation, routing, or integrated allocation and routing, marked with "X" under the relevant problem definition. Moreover, the "MCDM Approach" columns specify the solution approach used in the paper with a "X" mark under the employed approach, borrowing the categorization of Gutjahr and Nolz (2016). Specifically, the following abbreviations from Gutjahr and Nolz (2016) are used: [SC] for scalarization, [GP] for goal programming, [LO] for lexicographic optimization. Additionally, ϵ-Constraint (for epsilon constraint or augmented epsilon constraint method), [NSGA]-II (for non-dominated sorting genetic algorithm), and [MOGWO] (for multi-objective gray wolf optimizer) were derived and used for relevant articles. This is followed by columns for each sustainability metric identified in the papers, categorized under three dimensions. To improve table conciseness and readability, we use intuitive abbreviations for commonly used terms. For instance, Profit/Revenue is represented as "Prof./Rev." or the deviation between best-off and worst-off agencies is given as "Dev. btw. Best vs. Worst". The marks under columns specify if the metric was considered in the objective function (✓), as a constraint (+), or implicitly in the model (˜). The following subsections present the sustainability metrics considered for each dimension and provide a discussion on the multi-criteria optimization methods used in the FBSC literature.

Table 1: MCDM Solution Approaches and Sustainability Metrics from FBSC

	Prob. Def.			Economic				Environmental						Social												MCDM Approach							
				Pr./Cost				Waste				Ems.		Equity							Other													
Article	Allocation	Routing	Alloc. & Routing	Prof./Rev.	Cost	Travel Distance/Time	Resource Utilization	(Min.) Beneficiary Fill Rate	Undistributed Food Amount	Distributed Food Amount	Food Spoilage/Waste	GHG Emission	CO_2 Emission	Min. Fill Rate	Perfect Equity	Dev. fr. Perf. Eq./Demand	Neg. Dev. fr. Perf. Eq.	Dev. fr. Max Fill Rate	Dev. btw. Best vs Worst	Dev. Among Benefs.	Benef. Util./Demand Sat.	Food Variety	Nutr. Val/ Cals./Freshness	Job Cr./Volunt. Work	Odor fr. Food Waste	Tr. Dist. of Benefs.	[SC]	[LO]	[PO]	[GP]	NSGA-II	MOGWO	ϵ-Constraint
Alkaabneh et al. (2021)	X							✓												~		+	+									
Balcik et al. (2014)			X				✓			~			✓																			
Blackmon et al. (2021)	X			✓																	+				X							
Bonku et al. (2024)			X		✓		✓												✓						X							
Cheng et al. (2021)	X								✓							✓												X				
Cuevas-Ortuño and Gómez-Padilla (2017)	X			+																	+	✓										
Davis et al. (2014)			X		✓	+				+																						
Eisenhandler and Tzur (2019)			X						✓										✓						X							
Eisenhandler and Tzur (2022)			X		+	~			✓										✓						X							
Fianu and Davis (2018)	X														✓																	
Firouz et al. (2022)	X						✓										✓									X		X					
Ghahremani-Nahr et al. (2023)			X	✓	✓				✓												+	✓								X	X	X	
Ghoniem et al. (2013)			X	✓	✓																				X							
Ghorpade and Corlu (2022)		X		+																✓													
Gómez-Pantoja et al. (2021)	X			+																✓		✓				X							
Hasnain et al. (2021)	X			✓				✓							✓											X							
Islam and Ivy (2022)	X			✓				✓							+											X							
Kaviyani-Charati et al. (2022)			X	✓						✓		✓								✓			✓	✓					X		X		
Lien et al. (2014)	X						✓			~			✓																				
Mandal et al. (2021)			X ✓	✓						✓	✓	✓														X							
Martins et al. (2019)	X		✓	✓				✓			✓		✓							✓			✓		✓		X						
Nair et al. (2017)		X		✓									✓		✓			✓															
Nair et al. (2018)		X		✓						+										+													
Reihaneh and Ghoniem (2017)			X	✓																+					✓	X							
Reusken et al. (2024)			X	✓		✓														+													
Rey et al. (2018)			X	✓						+									✓							X							
Sengul Orgut et al. (2016)	X							✓							+																		
Sengul Orgut et al. (2017)	X			✓				✓						+						✓						X							
Sengul Orgut et al. (2018)	X								✓					+																			
Sengul Orgut and Lodree (2023)	X								✓	~					+																		
Solak et al. (2014)			X	✓																+					✓	X							
Stauffer et al. (2022)	X			✓				✓							+											X							
Suárez et al. (2024)	X					+			✓	~										+		✓				X							
Total Mentions	17	3	13	2	19	5	4	5	6	7	1	2	2	4	2	7	1	1	1	5	10	4	5	2	1	3	16	1	1	1	2	1	2

5.1.1 Sustainability Metrics

Economic sustainability metrics, as discussed in Table 1, were usually added to the objective function as cost minimization (Blackmon et al., 2021; Ghahremani-Nahr et al., 2023; Ghoniem et al., 2013; Hasnain et al., 2021; Islam and Ivy, 2022; Kaviyani-Charati et al., 2022; Mandal et al., 2021; Martins et al., 2019; Nair et al., 2018, 2017; Reihaneh and Ghoniem, 2017; Reusken et al., 2024; Rey et al., 2018; Sengul Orgut et al., 2017; Solak et al., 2014; Stauffer et al., 2022), or addressed as a budget constraint (Cuevas-Ortuño and Gómez-Padilla, 2017; Ghorpade and Corlu, 2022; Gómez-Pantoja et al., 2021). These costs include transportation costs relative to the distance traveled, employee costs in terms of working hours and job definitions, fixed operating costs of facilities and/or hubs, purchasing costs, and holding or disposal costs for undistributed food amounts. The minimum cost objective is used to ensure the efficient use of monetary and human resources, and budget constraints may be necessary for real-life situations where the resources are limited. Mandal et al. (2021) consider the perspective of the aggregator in FBSC, and define their profit as the difference between revenue (from tax exemptions) and costs (fixed and transportation costs, penalty for time windows, disposal cost of undistributed food) in the objective function. However, Eisenhandler and Tzur (2019) and Sengul Orgut et al. (2016) argue that an economic objective is not the primary aim of humanitarian operations, and there is a trade-off between a cost-objective, equity (distributing the donations in a way that does not leave anyone at a disadvantage) and effectiveness (distributing as much food as possible) objectives. Moreover, travel distance or time (Bonku et al., 2024; Davis et al., 2014; Eisenhandler and Tzur, 2022; Ghahremani-Nahr et al., 2023; Ghoniem et al., 2013) or use of resources (Davis et al., 2014; Eisenhandler and Tzur, 2022; Reusken et al., 2024; Suárez et al., 2024) are considered in the objective functions and model constraints. Therefore, using multi-criteria decision-making techniques to define and solve problems that balance conflicting objectives is necessary Gutjahr and Nolz (2016).

In **environmental sustainability metrics**, food waste is the most significant consideration in FB operations. It is incorporated into the objective function in two approaches: *(1)* minimizing the undistributed food amount (Hasnain et al., 2021; Islam and Ivy, 2022; Martins et al., 2019; Sengul Orgut et al., 2017, 2016; Stauffer et al., 2022), and *(2)* maximizing the distributed food amount (Balcik et al., 2014; Chen et al., 2017; Eisenhandler and Tzur, 2019, 2022; Ghahremani-Nahr et al., 2023; Sengul Orgut et al., 2018; Sengul Orgut and Lodree, 2023; Suárez et al., 2024) or food waste (Kaviyani-Charati et al., 2022; Mandal et al., 2021). Moreover, the amount of food wasted can be explicitly or implicitly considered in the constraints (Balcik et al., 2014; Chen et al., 2017; Lien et al., 2014; Nair et al., 2018; Rey et al., 2018; Sengul Orgut and Lodree, 2023; Suárez et al., 2024). Maximizing the (minimum) beneficiary fill rates is also studied as a way of preventing food waste (Alkaabneh et al., 2021; Balcik et al., 2014; Bonku et al., 2024; Firouz et al., 2022; Lien et al., 2014). Moreover, Kaviyani-Charati et al. (2022) considers the social disturbance due to the odor from wasted food in the objective function under social metrics; it must be noted that this metric implicitly decreases food waste as well. Other metrics such as CO_2 or GHG emissions are usually implicitly addressed when travel distance is minimized, although some studies explicitly define these metrics. Specifically, Kaviyani-Charati et al. (2022); Martins et al. (2019) minimize the CO_2 emission as a part of their respective objective functions, and Kaviyani-Charati et al. (2022); Mandal et al. (2021) include minimization of the GHG emissions in their objective functions.

The most studied **social sustainability metric** is equity as it is included in at least 21 papers. Beyond equity, satisfying the demand of beneficiaries is vastly studied. However, other social sustainability metrics

are yet to be explored in detail. Equity in the allocation and distribution of donations can be defined as ensuring an allocation where no person is at a disadvantage compared to others Sengul Orgut et al. (2012). It has been considered in various ways. First, some papers maximize the expected minimum fill rate of agencies (Balcik et al., 2014; Lien et al., 2014; Martins et al., 2019; Nair et al., 2018). Similarly, Eisenhandler and Tzur (2019, 2022) compare the allocated amount for each agency to minimize the inequalities (deviation) among different agencies. Perfect equity constraints are another way of ensuring each beneficiary receives a donation proportional to their need (Sengul Orgut et al., 2017; Sengul Orgut et al., 2018). Building on the perfect equity constraints, papers specify a maximum allowed deviation from perfect equity in their constraints (Islam and Ivy, 2022; Sengul Orgut et al., 2016; Sengul Orgut and Lodree, 2023; Stauffer et al., 2022) or minimize this deviation in the objective function (Fianu and Davis, 2018; Gómez-Pantoja et al., 2021; Nair et al., 2017). There can be different definitions for this deviation. Specifically, Nair et al. (2017) consider the deviation from the demand for each agency, and Fianu and Davis (2018) define equity as allocating an amount proportional to the need and maximizing it.

Other than equity, some social sustainability metrics are defined and used in the studies. Satisfying the demand of agencies or maximizing the utility of serving agencies are studied in various papers (Ghorpade and Corlu, 2022; Gómez-Pantoja et al., 2021; Kaviyani-Charati et al., 2022; Martins et al., 2019; Nair et al., 2018; Reihaneh and Ghoniem, 2017; Reusken et al., 2024; Sengul Orgut et al., 2017; Solak et al., 2014; Suárez et al., 2024). Variety of the distributed food (Alkaabneh et al., 2021; Blackmon et al., 2021; Cuevas-Ortuño and Gómez-Padilla, 2017; Ghahremani-Nahr et al., 2023) is usually incorporated into OR models while designing bundles or defining demand requirements, whereas the freshness and nutritional value/calories of the food are usually included in the objective functions (Cuevas-Ortuño and Gómez-Padilla, 2017; Ghahremani-Nahr et al., 2023; Gómez-Pantoja et al., 2021; Suárez et al., 2024). Few other social sustainability metrics are studied in the FB literature. For example, Martins et al. (2019) maximizes the social value of voluntary work, defined by its monetary value. Kaviyani-Charati et al. (2022) have constraints regarding job creation and meeting the needs of the beneficiaries. Finally, the distance beneficiaries need to travel is considered when the logistics costs are shared between the FBs and agencies (Martins et al., 2019; Reihaneh and Ghoniem, 2017; Solak et al., 2014).

5.1.2 Multi-Criteria Decision-Making Approaches

This section provides a summary of the MCDM solution approaches used in the FBSC to understand how different metrics (objectives) are considered simultaneously. A brief review of MCDM approaches mentioned in Gutjahr and Nolz (2016) is given in Appendix C.

In total, 9 papers consider a single objective and add constraints for other goals (e.g. minimizing cost while ensuring a maximum deviation from the perfect equity), and 16 use a scalarization approach [SC] (a weighted sum) with equal weights of different objectives (types of costs, equity terms, amount of food un/distributed) to reduce it into a single value. Using a weighted sum with different weights for objectives in the objective function or maintaining the maximum deviation from perfect equity would let the decision-maker analyze the trade-offs between equity and effectiveness when the model is solved with different parameter values. It is an intuitive approach that was widely used to combine multiple objectives into a single value. Alternative approaches such as Goal Programming [GP] or lexicographic optimization [LO] (including augmented [LO]) can provide better insights into trade-offs and objective prioritization. However,

both were only used in one paper each. Additionally, one paper compares the ϵ constraint methods with NSGA-II, while another expands this discussion by including the augmented ϵ constraint method, NSGA-II, and MOGWO. Therefore, employing different MCDM approaches from the literature could assist FB managers in their decision-making by showing the trade-offs or order of importance for different metrics more clearly.

5.2 Synthesis and Discussion

We synthesize our analysis of sustainability goals derived from the case study and the sustainability metrics from the FBSC literature in (Table 2). Specifically, we discuss how each goal from each dimension (economic, environmental, social) was defined and incorporated into decision-making models for donation collection, allocation, and distribution in the FB network. As we can observe from Table 2, the goals derived from the case study and metrics from the literature review were mostly consistent. Moreover, we observed that most of the papers reviewed included several sustainability metrics, whether as multi-objective or as an added constraint, which further stresses the importance of MCDM approaches to support better decision-making in FB operations.

Cost is the only economic sustainability goal that is mentioned in the case study, and it is widely studied as a metric in the literature as well. It is addressed as a type of operational/fixed cost or distance traveled, either in the objective function or in the constraints, in 19 out of 33 papers we reviewed. The revenue from unused funds or the profit generated are two other ways of incorporating economic sustainability into the decision-making models. Moreover, the use of vehicles, human, or monetary resources is addressed in the literature.

The environmental sustainability goal of decreasing food waste is incorporated either as an objective to maximize (minimize) the distributed (undistributed) food amount or some constraints limit the amount of waste that can be produced in the FBSC. Similarly, different formulations were used to refer to the GHG emissions as they can be calculated (and minimized) directly or as a proportion to the distance traveled. Another way to incorporate it is to calculate the CO_2 equivalent of any emissions from any activities. To the best of our knowledge, we did not encounter explicit sustainability metrics related to material recycling in the specific FBSC context. They were mentioned in the general SC literature (refer to Section 2.2 but are yet to be addressed in decision-making models for the FBSC. Studying ways to develop metrics for this goal could be a future research direction.

It was noted that equity, the most mentioned social sustainability metric, is at the heart of humanitarian operations, and therefore FB operations. This is reflected in the FBSC literature, as many studies have defined and incorporated equity into their models in several ways. Most studies defined equity in terms of the amount of food delivered, but some included the nutritional value of the food in this discussion. Maximizing the minimum fill rate among all agencies or minimizing the difference between the best-off and worst-off, or all pairs of agencies, can be considered in the objective functions. Moreover, incorporating equity into decision-making models can involve considering negative, positive, or all deviations from perfect equity or a requested amount (demand) of the agencies. Some papers define equity constraints to limit deviations from, or to ensure, perfect equity. Other important goals, such as the variety and nutritional value of the distributed food, were also addressed in the literature, although they were not as commonly discussed as equity. Some papers define different types of bundles to account for variety or directly use nutritional value

in the objective function to maximize. To the best of our knowledge, considering nutritious value and equity simultaneously was not studied often, and was included in one study; therefore is yet to be explored in more detail. Collaboration with local programs was another goal pointed out by the partner FBs in the case study. This collaboration and volunteer management were either addressed by defining a monetary value to volunteer work in the objective function or by considering the created jobs in the constraints in at least 2 papers.

To the best of our knowledge, we did not encounter any metric for social sustainability specifically quantifying and measuring the quality of a working environment or the direct distribution to agencies in the FBSC context, which were pointed out by the FB managers in our case study. In the CSC literature (Section 2.2), metrics related to work environment/conditions such as exposure to chemicals, employee benefits, education opportunities, or time-off privileges are mentioned. They can be adapted to the setting of the FBSC, where there are mostly volunteers as the staff, or new metrics for these goals could be developed as a future work direction. Moreover, a few studies have examined the distance traveled by beneficiaries to collect donations from the FB, assuming the beneficiaries are responsible for collecting the donations. Building on this, new metrics could be developed to measure the percentage of direct deliveries to beneficiaries, specifically in problems defined over different network levels.

Various MCDM approaches have been used to integrate conflicting objectives, such as minimizing costs while reducing undistributed food or maximizing beneficiary fill rates while minimizing total travel distance and deviations between beneficiaries. The most common approach involves assigning (equal or different) weights to combine these conflicting objectives into a single one. Notably, almost half of the studies mention scalarization according to our review, while one study considered both scalarization and Pareto optimization. Scalarization is easy to implement and interpret as it reduces a multi-objective problem to a single-objective one. However, other approaches may better capture decision-makers' priorities and provide deeper insights into trade-offs. For instance, one study employs lexicographic optimization, where the decision-maker defines a hierarchical order in terms of importance to different objectives, ensuring a prioritization between different goals. Another study proposes a robust goal programming approach, which could be useful when the decision-makers have specific target values for different objectives. Additionally, some papers compare NSGA-II, (augmented) ϵ constraint method, and MOGWO to understand the problem when tackled with different MCDM approaches. While it is not common to use techniques other than scalarization, exploring alternative MCDM approaches as a future work direction could be beneficial for better understanding the trade-offs and incorporating the decision maker's priorities into FB operation models.

Table 2: Distribution of sustainability metrics into decision-making modes

Case Study		Literature Review		Case Study		Literature Review	
Goal	**#**	**Metric**	**#**	**Goal**	**#**	**Metric**	**#**
Cost	16	objective - (max) profit/revenue	2	**Equity**	7	objective - (max) minimum fill rate	4
		objective - (min) cost	16			objective - (min) deviation from perfect equity/demand	3
		objective - (min) distance traveled	4			objective - (min) negative deviation from perfect equity	1
		objective - resource utilization	1			objective - (min) deviation between the best-off and worst-off beneficiaries	1
		constraints - cost	3			objective - (min) deviation from the maximum fill rate	1
		constraints - resource constraints	3			objective - (min) deviation among beneficiaries	4
Waste	10	objective - (max) (minimum) fill rate	5			constraints - perfect equity	2
		objective - (min) undistributed food amount	6			constraints - limit on max deviation from perfect equity	4
		objective - (max) distributed food amount	7			implicit - deviation among beneficiaries	1
		objective - (min) food spoilage/waste	2	**Collab. with local programs**	3	objective - (max) monetary value of volunteer work	1
		constraints - food spoilage/zero waste	3			constraints - job creation	1
		implicit - food spoilage/waste	4	**Working environment**	4	-	-
GHG Emission	3	objective - (min) distance traveled	2	**Direct distribution to agencies**	2	objective - (min) distance for beneficiaries to collect food	3
		objective - (min) CO_2 emission	2	**Nutritional value of distributed food**	1	objective - (max) nutritional value/calories/freshness	4
Material Recycling	3	-	-			constraints - nutritional value of distributed food	1
Variety of distributed food	9	constraints - variety of distributed food	4				

6 Conclusion

FBs work to eradicate hunger and minimize the environmental impact of food waste by collecting safe-to-consume but excess food from various donors, storing it, and distributing it to beneficiaries or agencies. To ensure the equity, effectiveness, and efficiency of their operational, tactical, and strategic operations, FBs use decision-making models. Sustainability is crucial to their operations, so it is essential to define and incorporate appropriate sustainability metrics into the decision-making process. These metrics can be adapted from the existing literature or developed based on the specific needs of FBs. In this study, we conducted a case study to understand the operations and identify important sustainability goals of FBs. We also reviewed the FBSC literature for metrics related to these goals. Ultimately, we identified which goals were already incorporated into the decision-making models for FBs and which goals still need to be defined and quantified. Since multiple objectives are generally of interest to FB managers, we also reviewed MCDM approaches included in current models.

Future research should focus on three key areas to advance sustainability in FBSC operations. First, further exploration of social sustainability metrics is essential. While equity has been widely studied, metrics for volunteer management, workplace safety, and social reintegration programs require deeper investigation and practical modeling frameworks to ensure long-term social impact. Second, addressing uncertainty in FBSC operations, particularly donation uncertainty and fluctuating demand, is crucial. Future research should develop MCDM models that effectively capture trade-offs between competing sustainability objectives under uncertainty, providing decision-makers with robust tools to manage unpredictability. Third, additional exploratory case studies are needed to examine the sustainability practices of food banks in different geographic and organizational contexts. Understanding diverse perspectives will provide valuable insights for developing adaptable and context-specific sustainability strategies in FBSC operations.

References

Ahi, P. and Searcy, C. (2015). An analysis of metrics used to measure performance in green and sustainable supply chains. Journal of Cleaner Production, 86:360–377.

Alkaabneh, F., Diabat, A., and Gao, H. O. (2021). A unified framework for efficient, effective, and fair resource allocation by food banks using an approximate dynamic programming approach. Omega, 100:102300.

Balcik, B., Iravani, S., and Smilowitz, K. (2014). Multi-vehicle sequential resource allocation for a nonprofit distribution system. IIE Transactions, 46(12):1279–1297.

Beamon, B. and Balcik, B. (2008). Performance measure in humanitarian relief chains. International Journal of Public Sector Management, 21:4–25.

Blackmon, L., Chan, R., Carbral, O., Chintapally, G., Dhara, S., Felix, P., Jagdish, A., Konakalla, S., Labana, J., McIlvain, J., Stone, J., Tang, C. S., Torres, J., and Wu, W. (2021). Rapid development of a decision support system to alleviate food insecurity at the los angeles regional food bank amid the covid-19 pandemic. Production and Operations Management, 30(10):3391–3407.

Blake, P. and Voegele, J. (2022). The impact of the war in ukraine on food security world bank expert answers. https://www.worldbank.org/en/news/video/2022/04/05/the-impact-of-the-war-in-ukraine-on-food-security-world-bank-expert-answers. Retrieved: September 22, 2022.

Bonku, R., Alkaabneh, F., and Davis, L. B. (2024). Collaborative vehicle routing for equitable and effective food allocation in nonprofit settings. Journal of Humanitarian Logistics and Supply Chain Management, ahead-of-print(ahead-of-print).

Boyatzis, R. E. (1998). Transforming qualitative information: Thematic analysis and code development. Thousand Oaks.

Bruce-Lockhart, C. and Terazono, E. (2022). How bad will the global food crisis get? https://www.ft.com/content/e44db6b3-7266-4188-8d08-79d678a61146. Retrieved: September 22, 2022.

Calzolari, T., Genovese, A., and Brint, A. (2022). Circular economy indicators for supply chains: A systematic literature review. Environmental and Sustainability Indicators, 13:100160.

Chavez, E., Conway, G., Ghil, M., and Sadler, M. (2015). An end-to-end assessment of extreme weather impacts on food security. Nature Climate Change, 5(11):997–1001.

Chen, L., Zhao, X., Tang, O., Price, L., Zhang, S., and Zhu, W. (2017). Supply chain collaboration for sustainability: A literature review and future research agenda. International Journal of Production Economics, 194:73–87. Special Issue: Innovations in Production Economics.

Cheng, J., Feng, X., and Bai, X. (2021). Modeling equitable and effective distribution problem in humanitarian relief logistics by robust goal programming. Computers Industrial Engineering, 155:107183.

Chopra, S. and Meindl, P. (2007). Supply Chain Management : Strategy, Planning, and Pperation. Upper Saddle River, NJ : Pearson Prentice Hall.

Cuevas-Ortuño, J. and Gómez-Padilla, A. (2017). Assembly of customized food pantries in a food bank by fuzzy optimization. Journal of Industrial Engineering and Management, 10(4).

Davis, L. B., Sengul, I., Ivy, J. S., Brock, L. G., and Miles, L. (2014). Scheduling food bank collections and deliveries to ensure food safety and improve access. Socio-Economic Planning Sciences, 48(3):175–188.

Eisenhandler, O. and Tzur, M. (2019). The humanitarian pickup and distribution problem. Operations Research, 67(1):10–32.

Eisenhandler, O. and Tzur, M. (2022). Multi-period collection and distribution problems and their application to humanitarian gleaning operations. IISE Transactions, 54(8):785–802.

Eisenhardt, K. M. (1989). Building theories from case study research. Academy of Management Journal, 14(4):523–550.

Eskandarpour, M., Dejax, P., Miemczyk, J., and Péton, O. (2015). Sustainable supply chain network design: An optimization-oriented review. Omega, 54:11–32.

Eslami, Y., Dassisti, M., Lezoche, M., and Panetto, H. (2019). A survey on sustainability in manufacturing organisations: dimensions and future insights. International Journal of Production Research, 57(15-16):5194–5214.

FAO, IFAD, U. W. and WHO (2022). The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable. FAO.

Feeding America (2022). The Feeding America network. https://www.feedingamerica.org/our-work/food-bank-network. Retrieved: September 22, 2022.

Fianu, S. and Davis, L. B. (2018). A markov decision process model for equitable distribution of supplies under uncertainty. European Journal of Operational Research, 264(3):1101–1115.

Firouz, M., Li, L., Cobb, B., and Shao, F. (2022). On the equity-efficiency trade-off in food-bank network operations. Journal of the Operational Research Society, 0(0):1–22.

Food Banks of Quebec (2023). Rapport annuel 2022-2023. https://banquesalimentaires.org/wp-content/uploads/2023/06/BAQ_RA_22_23-VF.pdf. Retrieved: May 28, 2024.

Food Banks Quebec (2024). Who we are.

Ghahremani-Nahr, J., Ghaderi, A., and Kian, R. (2023). A food bank network design examining food nutritional value and freshness: A multi objective robust fuzzy model. Expert Systems with Applications, 215:119272.

Ghoniem, A., Scherrer, C. R., and Solak, S. (2013). A specialized column generation approach for a vehicle routing problem with demand allocation. Journal of the Operational Research Society, 64(1):114–124.

Ghorpade, T. and Corlu, C. G. (2022). A simheuristic algorithm for the stochastic one-commodity pickup and delivery travelling salesman problem. Journal of Simulation, 0(0):1–21.

Gómez-Pantoja, J. Á., Salazar-Aguilar, M. A., and González-Velarde, J. L. (2021). The food bank resource allocation problem. TOP, 29(1):266–286.

Gutjahr, W. J. and Nolz, P. C. (2016). Multicriteria optimization in humanitarian aid. European Journal of Operational Research, 252(2):351–366.

Hasnain, T., Sengul Orgut, I., and Ivy, J. S. (2021). Elicitation of preference among multiple criteria in food distribution by food banks. Production and Operations Management, 30(12):4475–4500.

Islam, M. H. and Ivy, J. S. (2022). Modeling the role of efficiency for the equitable and effective distribution of donated food. OR Spectrum, 44(2):485–534.

Kafa, N. and Jaegler, A. (2021). Food losses and waste quantification in supply chains: a systematic literature review. British Food Journal, 123(11):3502–3521.

Kaviyani-Charati, M., Ameli, M., Heidarzadeh Souraki, F., and Jabbarzadeh, A. (2022). Sustainable network design for a non-profit food bank supply chain with a heterogeneous fleet under uncertainty. Computers Industrial Engineering, 171:108442.

Lien, R. W., Iravani, S. M. R., and Smilowitz, K. R. (2014). Sequential resource allocation for nonprofit operations. Operations Research, 62(2):301–317.

Mahmoudi, M., Shirzad, K., and Verter, V. (2022). Decision support models for managing food aid supply chains: A systematic literature review. Socio-Economic Planning Sciences, 82. Cited by: 2.

Mandal, J., Mitra, R., Gupta, V. K., Subramanian, N., Kayikci, Y., and Tiwari, M. K. (2021). Optimal allocation of near-expiry food in a retailer-foodbank supply network with economic and environmental considerations: An aggregator's perspective. Journal of Cleaner Production, 318:128481.

Martins, C., Melo, M., and Pato, M. (2019). Redesigning a food bank supply chain network in a triple bottom line context. International Journal of Production Economics, 214:234–247.

McCutcheon, D. M. and Meredith, J. R. (1993). Conducting case study research in operations management. Journal of Operations Management, 11(3):239–256.

McElroy, M. W. and Van Engelen, J. M. (2012). Corporate sustainability management: The art and science of managing non-financial performance. Routledge.

Moisson Mauricie Centre-du-Québec (2025). Notre impact. https://www.moisson-mcdq.org/qui-sommes-nous/notre-impact/. Retrieved: March 13, 2025.

Moreno-Camacho, C. A., Montoya-Torres, J. R., Jaegler, A., and Gondran, N. (2019). Sustainability metrics for real case applications of the supply chain network design problem: A systematic literature review. Journal of Cleaner Production, 231:600–618.

Nair, D., Grzybowska, H., Fu, Y., and Dixit, V. (2018). Scheduling and routing models for food rescue and delivery operations. Socio-Economic Planning Sciences, 63:18–32.

Nair, D. J., Rey, D., and Dixit, V. V. (2017). Fair allocation and cost-effective routing models for food rescue and redistribution. IISE Transactions, 49(12):1172–1188.

Narayanan, A. and Altay, N. (2021). Ambidextrous humanitarian organizations. Annals of Operations Research.

National Geographic Society (2022). Hunger and war. https://education.nationalgeographic.org/resource/hunger-and-war. Retrieved: September 22, 2022.

Nawazish, M., Nandakumar, M. K., and Mateen, A. (2023). Are humanitarian supply chains sustainable? a systematic review and future research themes. Benchmarking: An International Journal, ahead-of-print(ahead-of-print).

Qorri, A., Mujkić, Z., and Kraslawski, A. (2018). A conceptual framework for measuring sustainability performance of supply chains. Journal of Cleaner Production, 189:570–584.

Radimer, K. L. and Radimer, K. L. (2002). Measurement of household food security in the usa and other industrialised countries. Public Health Nutrition, 5(6a):859–864.

Reihaneh, M. and Ghoniem, A. (2017). A multi-start optimization-based heuristic for a food bank distribution problem. Journal of the Operational Research Society, 69.

Reusken, M., Laporte, G., Rohmer, S. U., and Cruijssen, F. (2024). Vehicle routing with stochastic demand, service and waiting times — the case of food bank collection problems. European Journal of Operational Research, 317(1):111–127.

Rey, D., Almi'ani, K., and Nair, D. J. (2018). Exact and heuristic algorithms for finding envy-free allocations in food rescue pickup and delivery logistics. Transportation Research Part E: Logistics and Transportation Review, 112:19–46.

Rivera, A. F., Smith, N. R., and Ruiz, A. (2023). A systematic literature review of food banks' supply chain operations with a focus on optimization models. Journal of Humanitarian Logistics and Supply Chain Management, 13(1):10 – 25. Cited by: 0; All Open Access, Hybrid Gold Open Access.

Sengul Orgut, I., Ivy, J., and Uzsoy, R. (2012). Modeling for equitable food distribution under capacity constraints.

Sengul Orgut, I., Ivy, J., and Uzsoy, R. (2017). Modeling for the equitable and effective distribution of food donations under stochastic receiving capacities. IISE Transactions, 49(6):567–578.

Sengul Orgut, I., Ivy, J., Uzsoy, R., and Wilson, J. R. (2016). Modeling for the equitable and effective distribution of donated food under capacity constraints. IIE Transactions, 48(3):252–266.

Sengul Orgut, I., Ivy, J. S., Uzsoy, R., and Hale, C. (2018). Robust optimization approaches for the equitable and effective distribution of donated food. European Journal of Operational Research, 269(2):516–531.

Sengul Orgut, I. and Lodree, E. J. (2023). Equitable distribution of perishable items in a food bank supply chain. Production and Operations Management. Cited by: 0.

Solak, S., Scherrer, C., and Ghoniem, A. (2014). The stop-and-drop problem in nonprofit food distribution networks. Annals of Operations Research, 221(1):407–426.

Stauffer, J. M., Vanajakumari, M., Kumar, S., and Mangapora, T. (2022). Achieving equitable food security: How can food bank mobile pantries fill this humanitarian need. Production and Operations Management, 31(4):1802–1821.

Suárez, C. A., Guaño, W. A., Pérez, C. C., and Roa-López, H. (2024). Multi-objective optimization for perishable product dispatch in a fefo system for a food bank single warehouse. Operations Research Perspectives, 12:100304.

Taticchi, P., Garengo, P., Nudurupati, S. S., Tonelli, F., and Pasqualino, R. (2015). A review of decision-support tools and performance measurement and sustainable supply chain management. International Journal of Production Research, 53(21):6473–6494.

Tuni, A., Rentizelas, A., and Duffy, A. (2018). Environmental performance measurement for green supply chains. International Journal of Physical Distribution & Logistics Management, 48(8):765–793.

United Nations (2015). Integrating the three dimensions of sustainable development. https://www.unescap.org/sites/default/files/Integrating%20the%20three%20dimensions%20of%20sustainable%20development%20A%20framework.pdf. Retrieved: December 13, 2022.

United Nations (2022a). The sustainable development goals report 2022. https://unstats.un.org/sdgs/report/2022/The-Sustainable-Development-Goals-Report-2022.pdf. Retrieved: September 21, 2022.

United Nations (2022b). The 17 goals. https://sdgs.un.org/goals. Retrieved: December 13, 2022.

United Nations (2025). Ensure sustainable consumption and production patterns. https://unstats.un.org/sdgs/report/2022/goal-12/. Retrieved: March 19, 2025.

Van Wassenhove, L. N. (2006). Humanitarian aid logistics: supply chain management in high gear. Journal of the Operational Research Society, 57(5):475–489.

Yin, R. K. (2009). Case Study Research: Design and Methods. Thousand Oaks: Sage publications, fourth edition.

Zajac, S. and Huber, S. (2021). Objectives and methods in multi-objective routing problems: a survey and classification scheme. European Journal of Operational Research, 290(1):1–25.

Zarei, M. H., Carrasco-Gallego, R., and Ronchi, S. (2019). On the role of regional hubs in the environmental sustainability of humanitarian supply chains. Sustainable Development, 27(5):846–859.

Zimmer, K., Fröhling, M., and Schultmann, F. (2016). Sustainable supplier management – a review of models supporting sustainable supplier selection, monitoring and development. International Journal of Production Research, 54(5):1412–1442.

A Positioning of FBSC between CSC and HSC

Table 3: Positioning of food bank operations, inspired from (Beamon and Balcik, 2008; Narayanan and Altay, 2021; Van Wassenhove, 2006)

Field	**Commercial Supply Chains**	**Humanitarian Supply Chains: Development Activities**	**Humanitarian Supply Chains: Sustenance Aid Food Bank Operations**	**Humanitarian Supply Chains: Disaster Aid Relief Chain**
Objective	Maximizing profit and customer satisfaction	Developing the community with aid programs	Help the community with sustenance-aid programs	Minimize loss of life and human suffering
Urgency	No	No	Yes	Yes
Demand pattern	Low uncertainty	Middle uncertainty	Middle uncertainty	High uncertainty in terms of location, type, and size
Income type	Revenue from sales	Donations	Donations	Donations
Lead time	Industry-dependent	Depends on the severity of need	As short as possible for perishable products, may depend for non-perishable products	As short as possible
Infrastructure, environment & equipment	Usually adequate infrastructure and latest technological equipment	Low-income environments, relatively good infrastructure	High-income or low-income environments, relatively good infrastructure	Greatly damaged or no infrastructure
Coordination	Coordination between chosen organizations and partners	Coordination between NGOs, businesses and governments	Coordination between NGOs, businesses and governments	Little to no coordination due to the emergency environment
Information systems	Mostly advanced technology	May benefit from advanced technologies	May benefit from advanced technologies	Unreliable and incomplete or no information
Performance measuring systems	Resource performance metrics to target efficiency	Both resource and output performance metrics to target efficiency and effectiveness	Both resource and output performance metrics to target efficiency, equity, and effectiveness	Output performance metrics such as response time or number of people helped
Operation frequency	Regular operations	Regular operations	Both regular and irregular operations	Irregular operations
Staff	Paid employees	Mostly volunteers	Paid employees and volunteers	Mostly volunteers

B Questions Asked to FBs

Indicate the importance (1=not at all important; 5=very important; or the fact that it is not applicable in your context “n/a”) that you attribute to each of the following sustainable development goals in the particular context of food banks:

Environmental Pillar

1. Minimize waste (number of kg of food discarded)
2. Minimize greenhouse gas emissions caused by transportation

3. Allow the redistribution of food directly to beneficiaries to reduce delays and ensure the freshness of certain more perishable foods
4. Minimize energy use (heating/cooling, electricity, etc.)
5. Minimize water use
6. Rather than scrapping, maximize the amount of material recovered or recycled

Social Pillar

1. Distribute food equitably between the organizations, i.e. in proportion to the number of beneficiaries served [i: Organization A helps 75 people and Organization B helps 25 people. If your food bank has 100 boxes to distribute, it would give 75 to Organization A and 25 to Organization B.]
2. Distribute the food equitably between the organizations, that is to say, according to what they ask for [i: Organization A helps 75 people and Organization B helps 25 people. If the food bank has 100 boxes to distribute and Organization A wants 50 and Organization B wants 30, the food bank will distribute the requested quantities: 50 to Organization A and 30 to Organization B.]
3. Maximize the nutritional value of the food distributed
4. Maximize the variety of food distributed
5. Collaborate with social reintegration and employability programs for people with functional limitations
6. Ensure a healthy and safe environment for employees and volunteers

Economic Pillar

1. Minimize operational costs (warehousing, transportation, etc.)

C Common MCDM Approaches

(1) Pareto optimization [PO] helps reduce the set of feasible solutions using Pareto optimal solutions (solutions that dominate others in all objectives), specifically when combining different criteria under a single objective is not easy or impossible (Gutjahr and Nolz, 2016). (2) Lexicographic optimization [LO] considers the objectives one by one with a given importance order. Specifically, the model is solved for each objective while maintaining the (near) optimal values of the previous (more important) objectives via new constraints at each step. It is important to note that the trade-offs are not easily distinguishable when this method is used (Gutjahr and Nolz, 2016). (3) Scalarization [SC] is used to reduce multiple objectives into a single objective, usually using a weighted sum of all objectives (Gutjahr and Nolz, 2016). (4) Goal Programming [GP] requires the decision-maker to assign target values for each one of the objectives. Then, using different approaches, the models can be solved to try to reach those targets (Gutjahr and Nolz, 2016). (5) Compromise Programming [CP] takes an ideal solution, usually formed by the best possible values for each objective, thus an infeasible point, and tries to reach that ideal objective function value (Gutjahr and Nolz, 2016). Lastly, (6) Analytic Hierarchy Process [AHP] compares and ranks a finite set of possible solutions according to the decision-maker's goals or criteria (Gutjahr and Nolz, 2016).

D Review Articles for Sustainability Metrics in Supply Chains

Paper	SC	Context	# Articles
Calzolari et al. (2022)	C	Circular SC performance	203
Eskandarpour et al. (2015)	C	General SC network design	87
Eslami et al. (2019)	C	Manufacturing SC	115
Kafa and Jaegler (2021)	C	Food waste and loss quantification	117
Moreno-Camacho et al. (2019)	C	General SC design	113
Qorri et al. (2018)	C	Sustainable and green SC	104
Taticchi et al. (2015)	C	Decision tools for Sustainable and green SC	384
Tuni et al. (2018)	C	Green SC	78
Zimmer et al. (2016)	C	Supplier selection	143
Nawazish et al. (2023)	H	Disaster relief	44

Table 4: Literature reviews used for understanding the existing sustainability metrics in SCM